# Impact of Long-range Wakefields on XLS two-pulse operation

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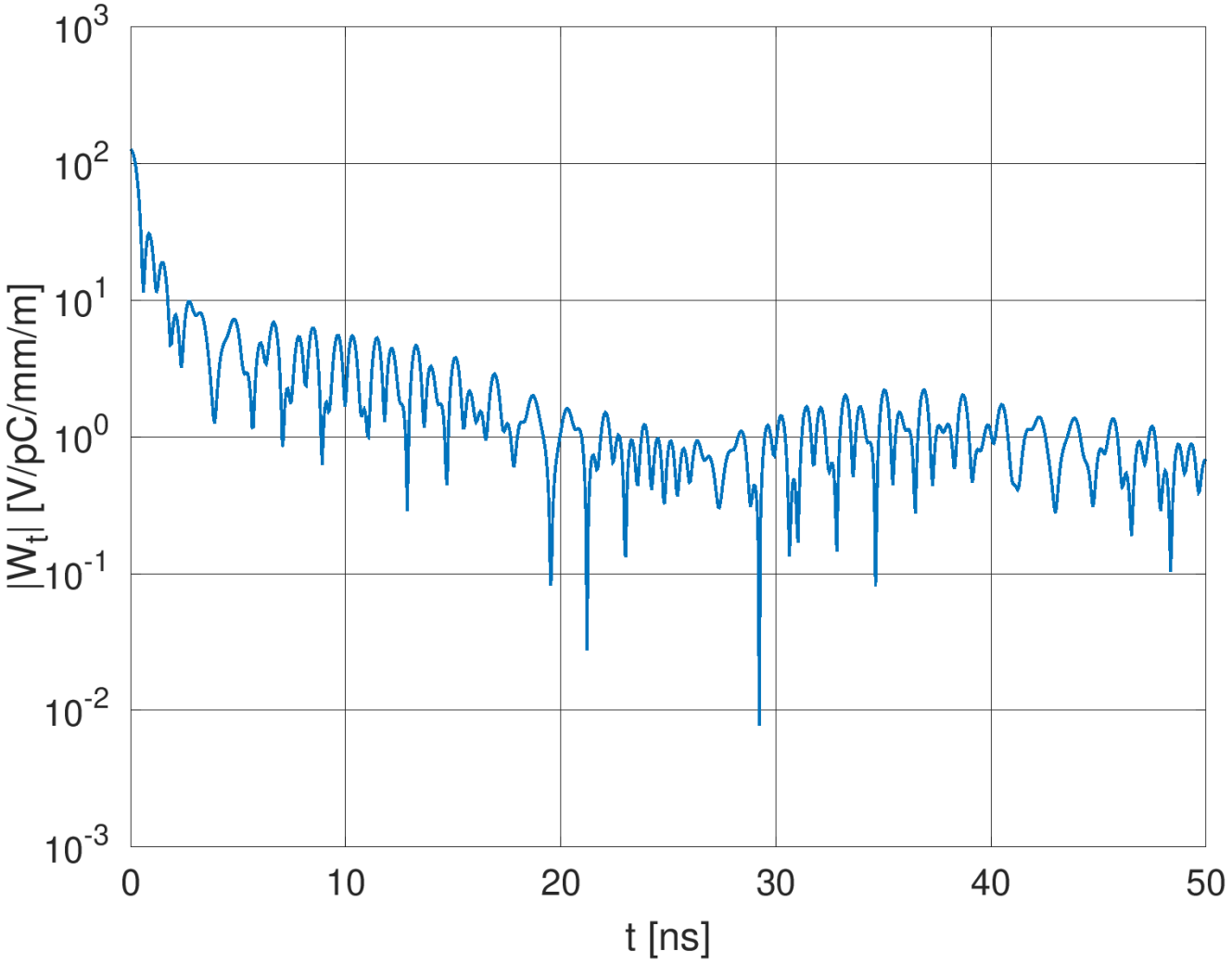
# Long-range wakefields in the CompactLight accelerating structure




Superposition of dipole modes:
* Freq, Amplitude, Q factor

Peak of absolute value is
126 V/pC/mm/m

$W_t$ (166 ps) = -109.381 V/pC/mm/m

$W_t$ (333 ps) = 20.038 V/pC/mm/m

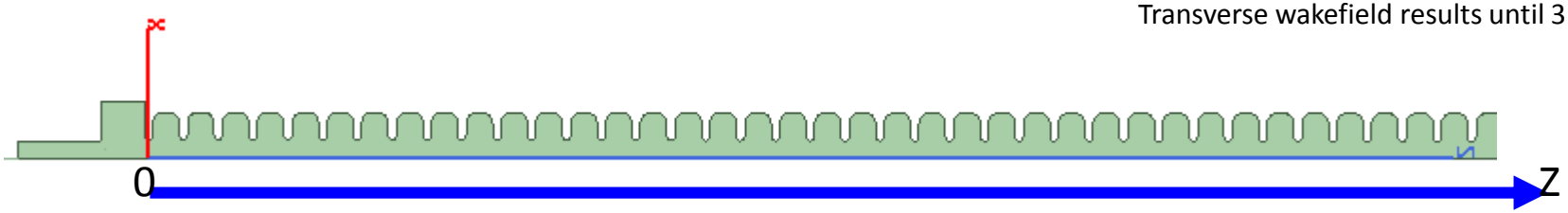
$W_t$ (500 ps) = 25.3327 V/pC/mm/m

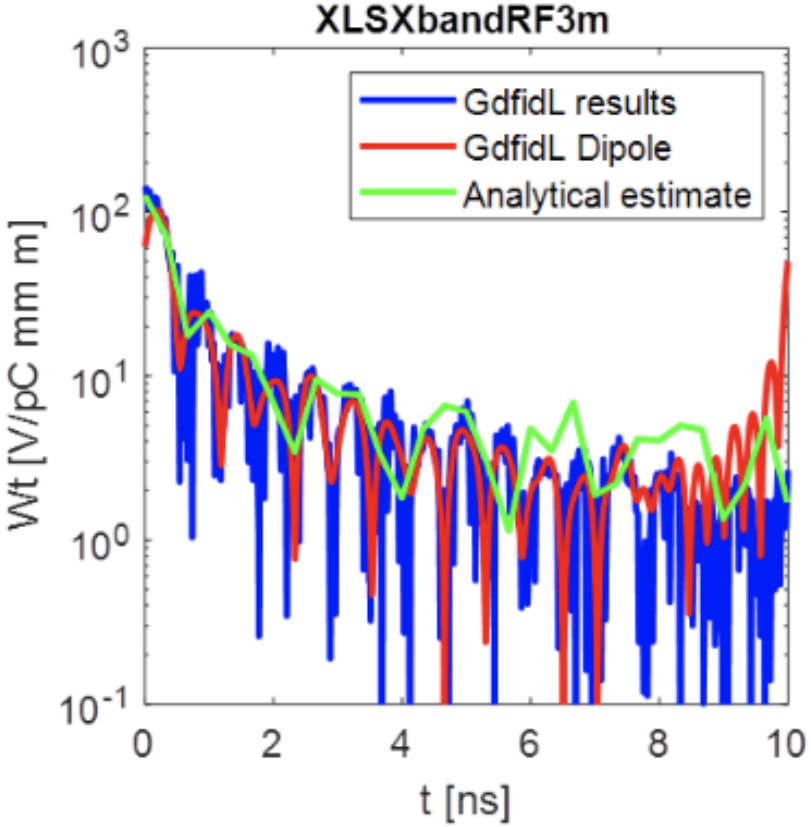
Alexej Grudiev: "Time scale of the suppression due to detuning:
tau ~ 1/deltaf1, where $\Delta f_1$ is the difference between min and max dipole frequencies, typically first and last cells. In that case we have $\Delta f_1$ = 17.1-15.4 = 1.7 GHz => tau ~ 0.6ns, so placing second bunch at this spacing you will fully profit from the detuning, as it is nicely shown in the plot below."

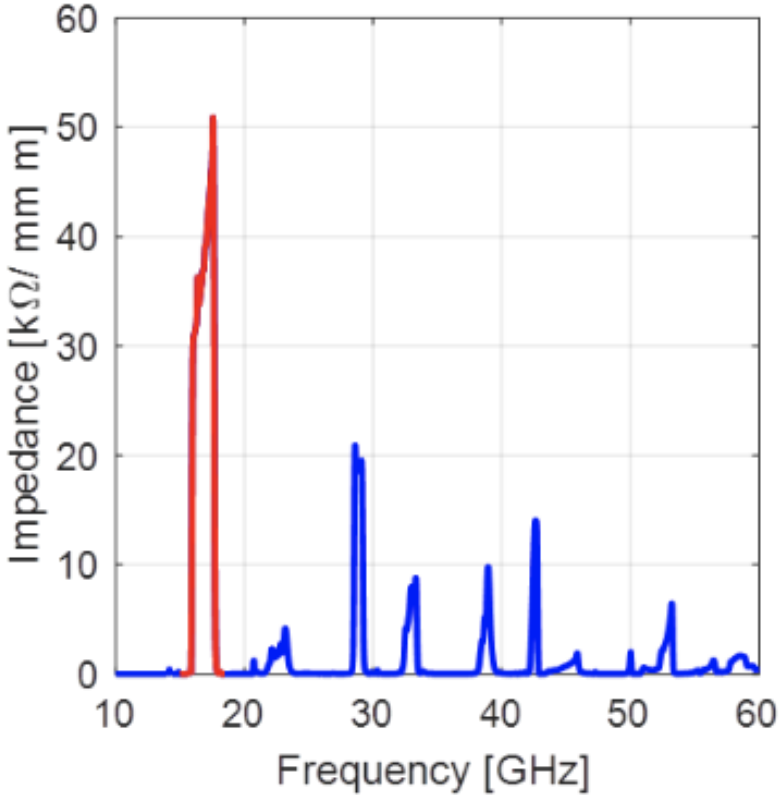
Courtesy of A. Grudiev

# Gdfidl calculations

XLS X-band RF structure
N=109 cell
L=908.188 mm
Transverse wakefield results until 3 meters

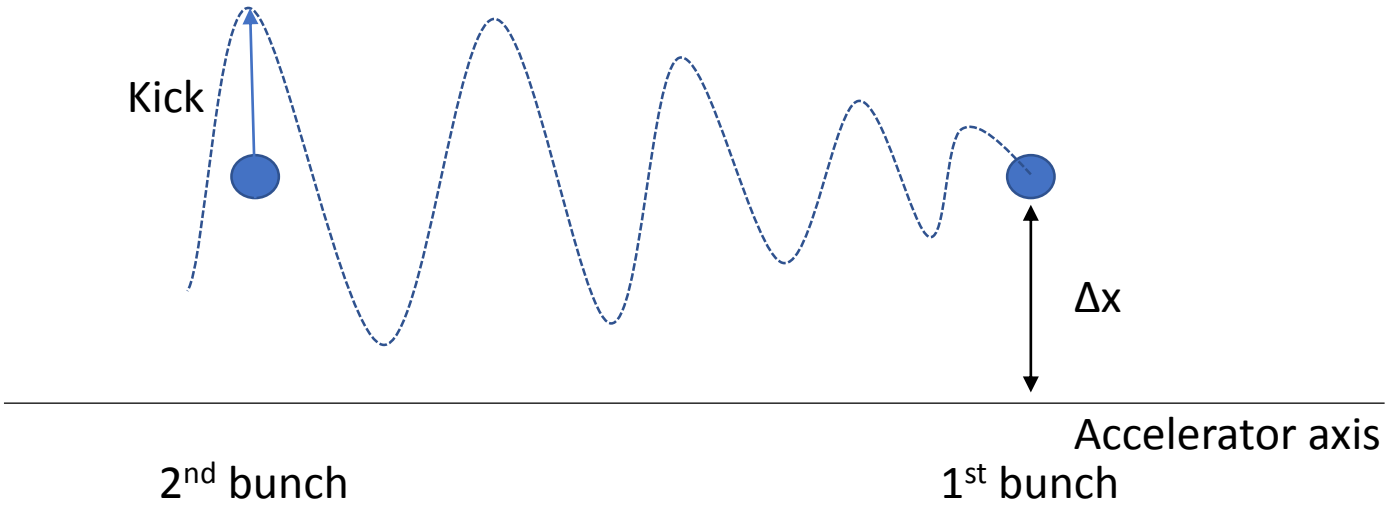



Courtesy of X. Wu

# Effect of LR wakes




The 2nd bunch is kicked, with kick proportional to

Δx' prop. to Wt(bunch spacing) * Δx * bunch charge * RF length

Wt is expressed in V/pC/mm/m.

Given an initial injection offset, we look at the *amplitude amplification factor*:

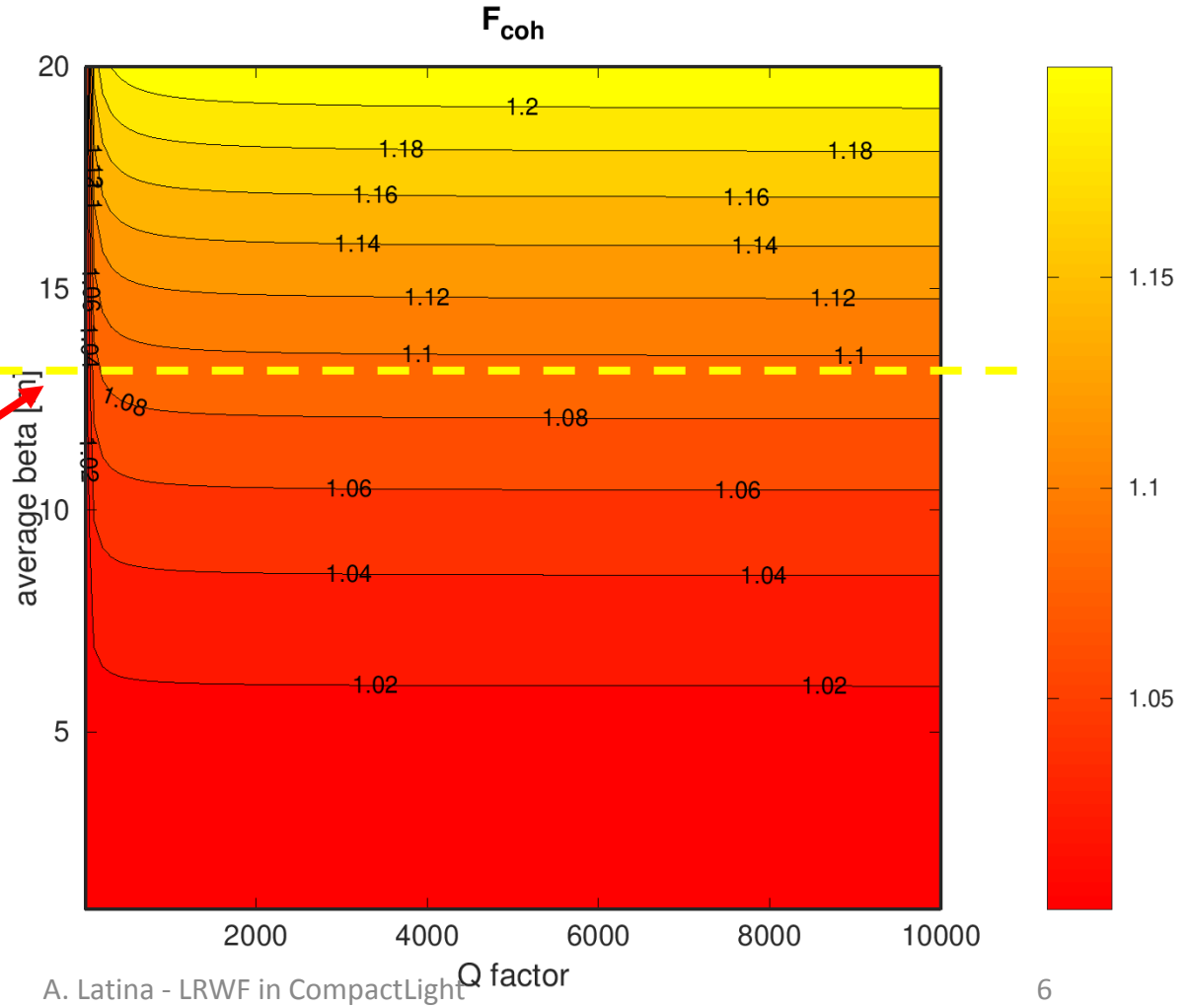
$$A = \frac{X_{2\text{st bunch}}}{X_{1\text{st bunch}}}$$ @ linac end

# Analytic estimates of jitter amplification factor (function of <β>) at 333 ps

Using the computed LR Wakes

Assumptions:
G = 66 MV/m
Bunch charge = 75 pC
Bunch spacing = 0.333 ns

Reasonable number?



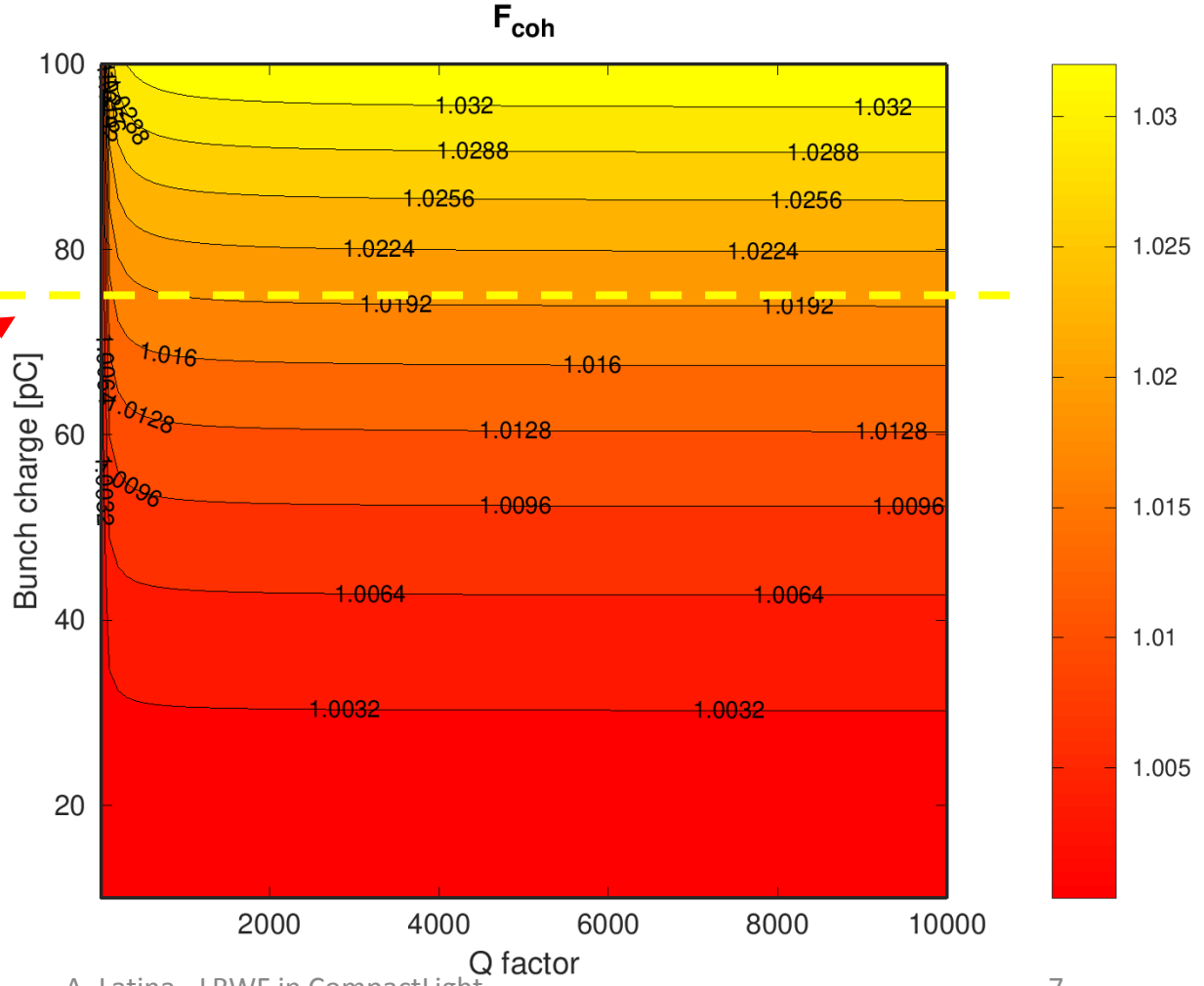

Ref: D. Schulte, "Multi-Bunch calculations in the CLIC Main LINAC", PAC 2009

# Analytic estimates of jitter amplification factor (function of bunch charge) at 333 ps

Using the computed LR Wakes

Assumptions:
G = 66 MV/m
<β> = 6 m
Bunch spacing = 0.333 ns

75 pC



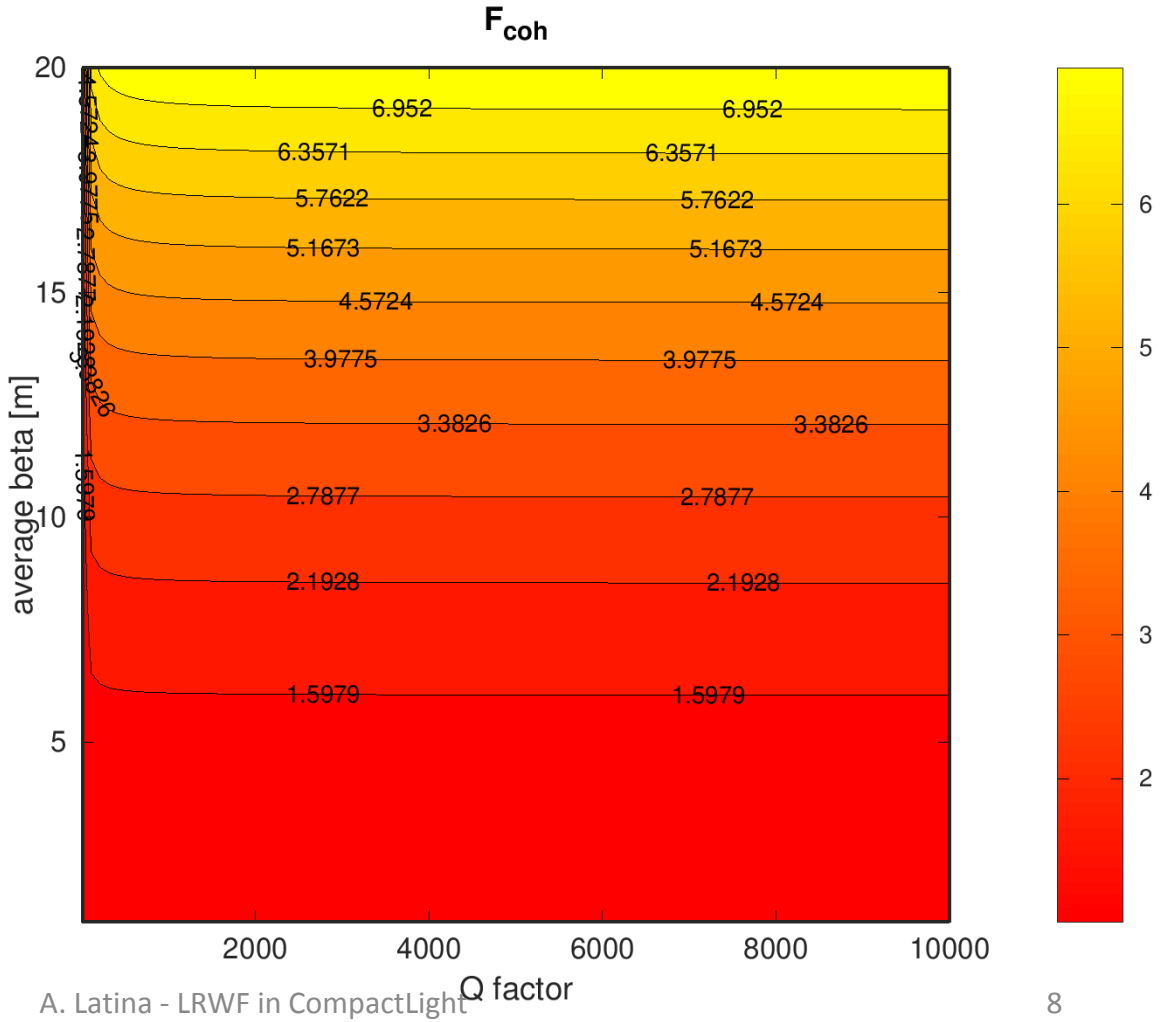



Ref: D. Schulte, "Multi-Bunch calculations in the CLIC Main LINAC", PAC 2009

# Analytic estimates of jitter amplification factor (function of <β>) at 166 ps

Using the computed LR Wakes

Assumptions:
G = 66 MV/m
Bunch charge = 75 pC
Bunch spacing = 0.166 ns




More problematic

Ref: D. Schulte, "Multi-Bunch calculations in the CLIC Main LINAC", PAC 2009

# Tracking simulations /I

- Simplified lattice with regular FODO structure:
  - 72 degrees phase advance / cell ( $<\beta> = 6$ m )
  - 4 accelerating structures every two consecutive quads
  - Energy from 300 MeV to 5.5 GeV
  - No bunch compression
  - No energy spread optimisation

- Simplified LRWF: deflecting kick attached to each structure, with strength scanned in the range

$$[\ 0\ ..\ 100\ ]\ \text{V/pC/m/mm}$$

- Beam parameters (looking at second bunch):
  - Initial Energy spread = 0.5%
  - Bunch length = 25 um (85 fs)
  - Bunch charge = 75 pC
  - Initial emittance 0.2 mm.mrad

# Tracking simulations /II

- Structures have been misaligned by
  - 0 μm rms
  - 10 μm rms
  - 100 μm rms

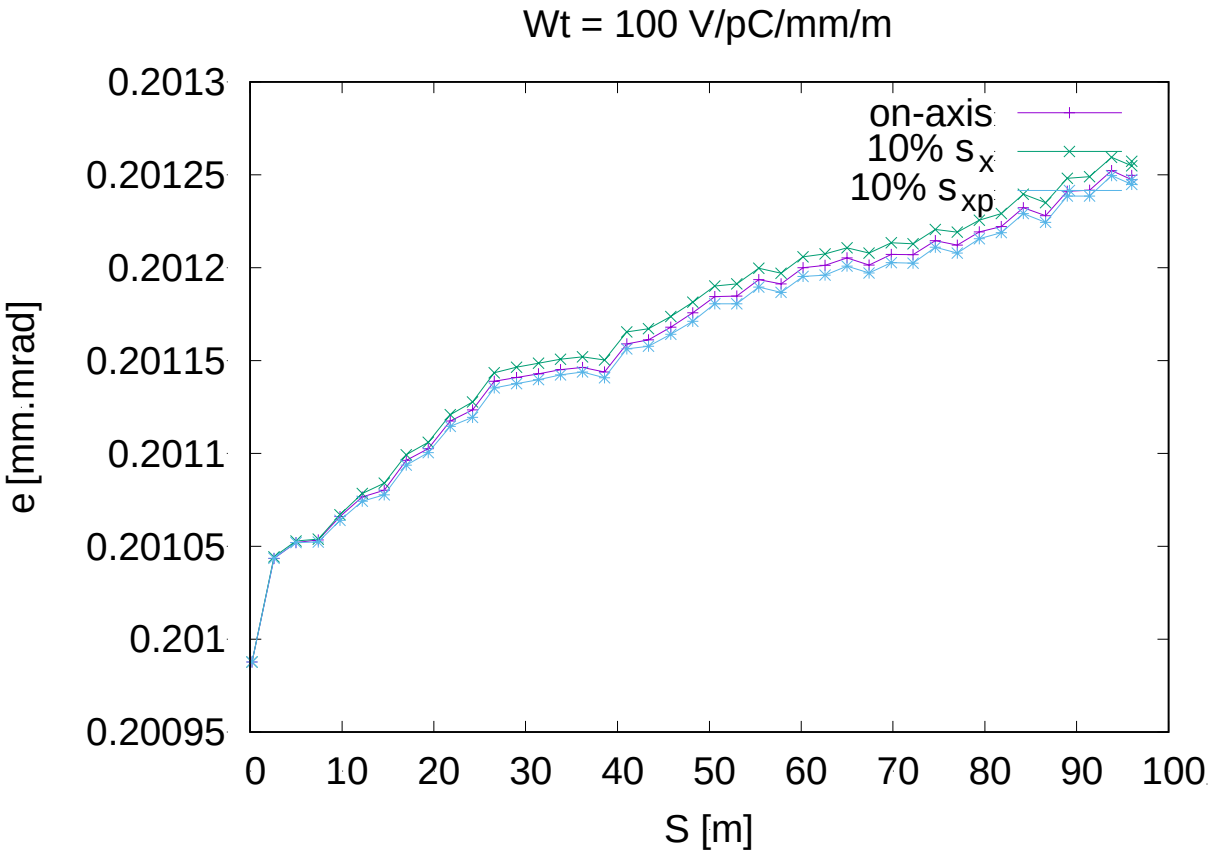
Looked at:

1. Impact on emittance
2. Incoming beam jitter amplification
   - 10% of initial horizontal beam size / divergence (i.e. jitter rms = 5 um)

# Impact of misalignments and LRWF on the emittance of the second bunch

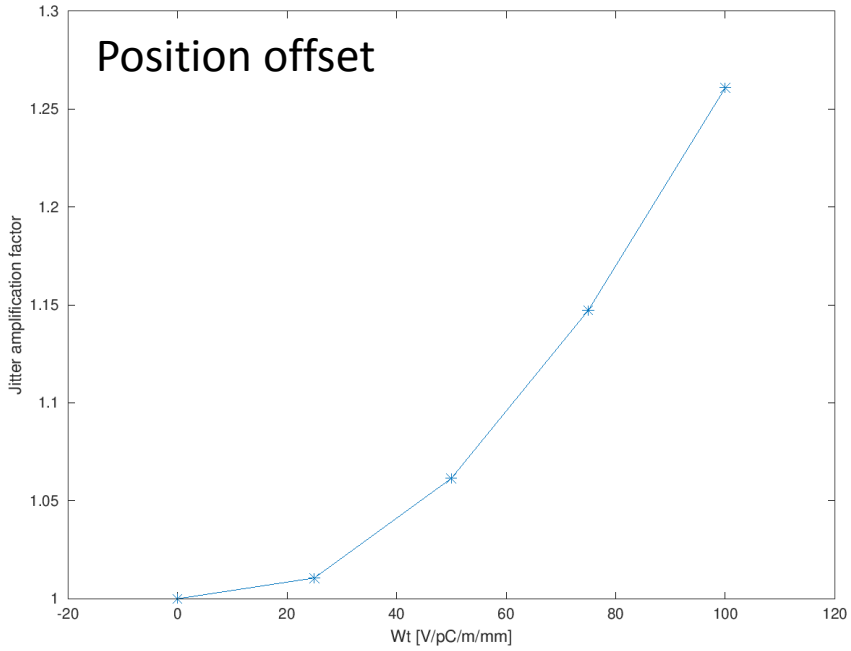
100 um rms misalignment ot structures

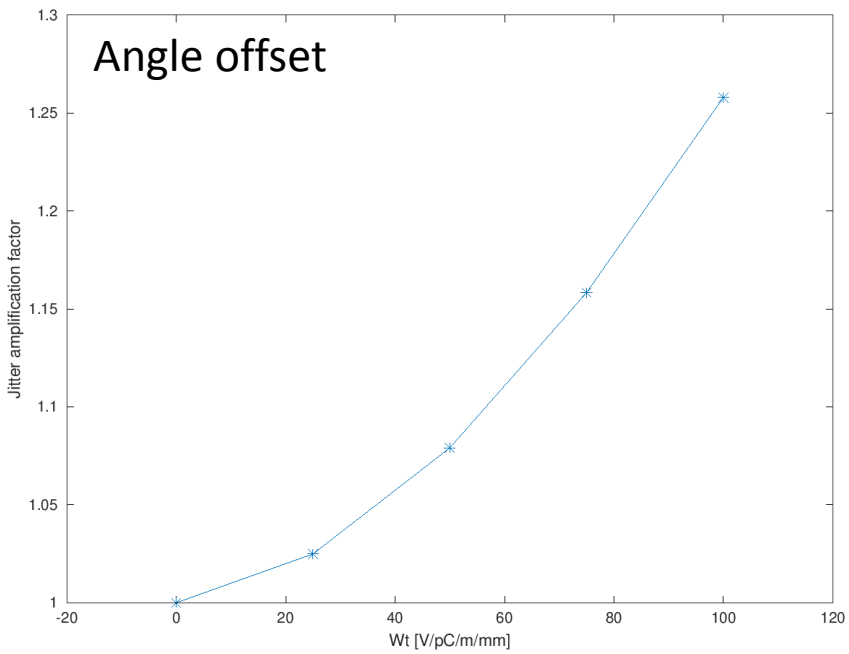
Each curve is the average of 100 randomly misaligned linacs



# Amplification factor at 2nd bunch

- Assume perfect alignment
- Off-axis beam injected with 10% $\sigma_{x/xp}$ offset

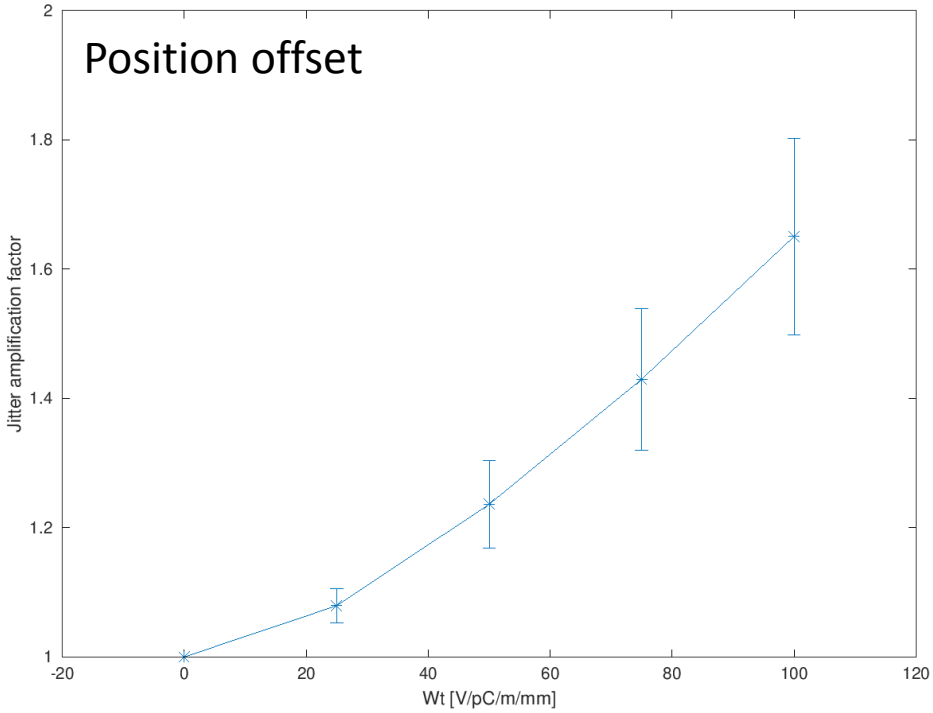


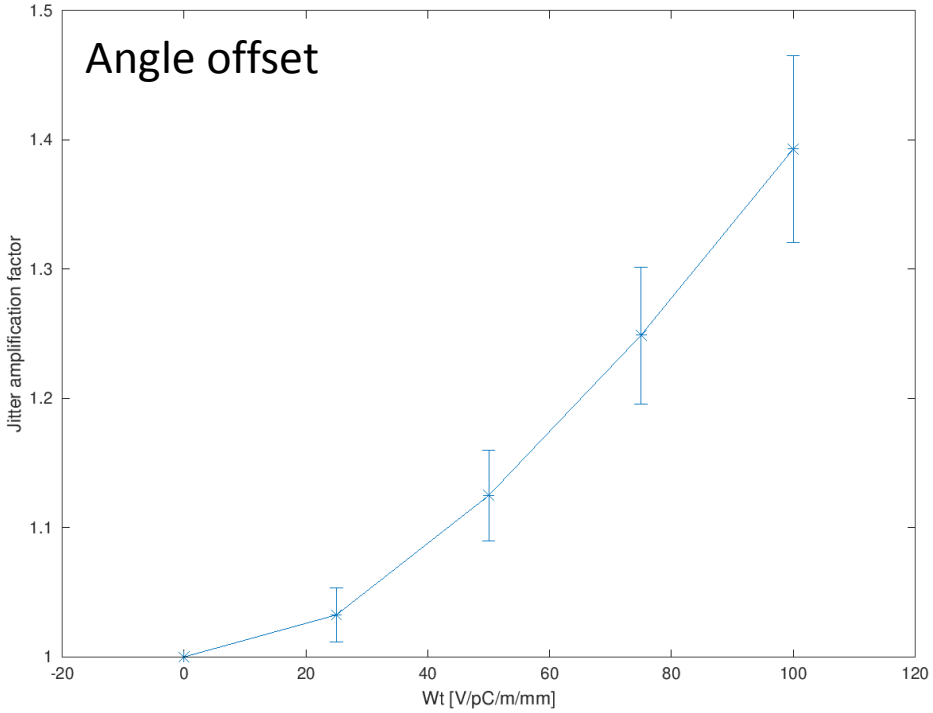




Confirms the analytical calculations

# Amplification factor at 2nd bunch

- Assume 10 um rms misalignment
- Off-axis beam injected with 10% $\sigma_{x/xp}$ offset
- 100 random misaligned machines simulated

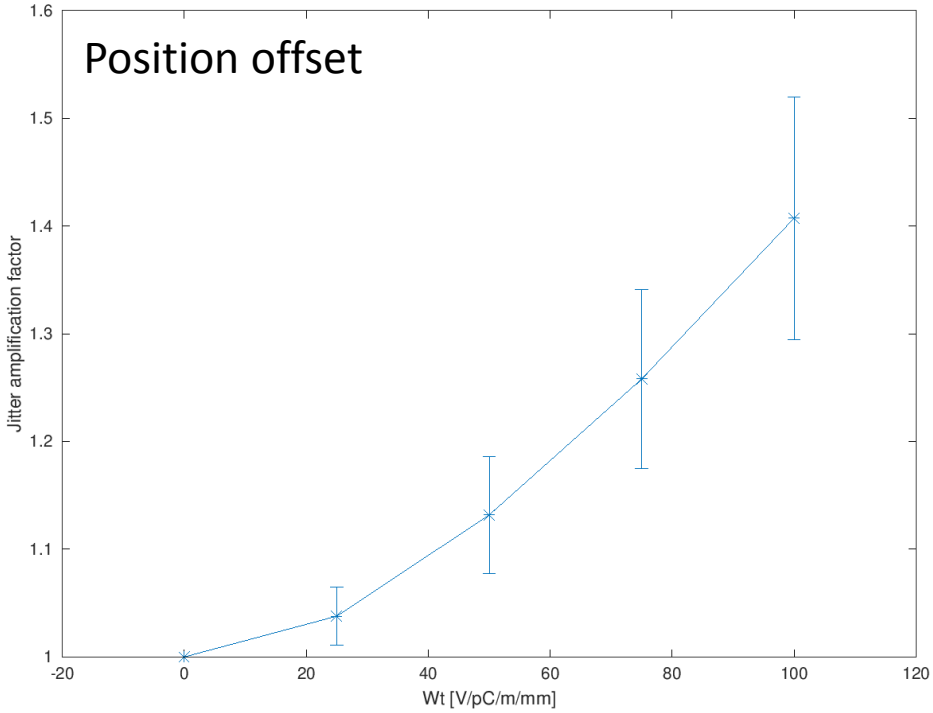


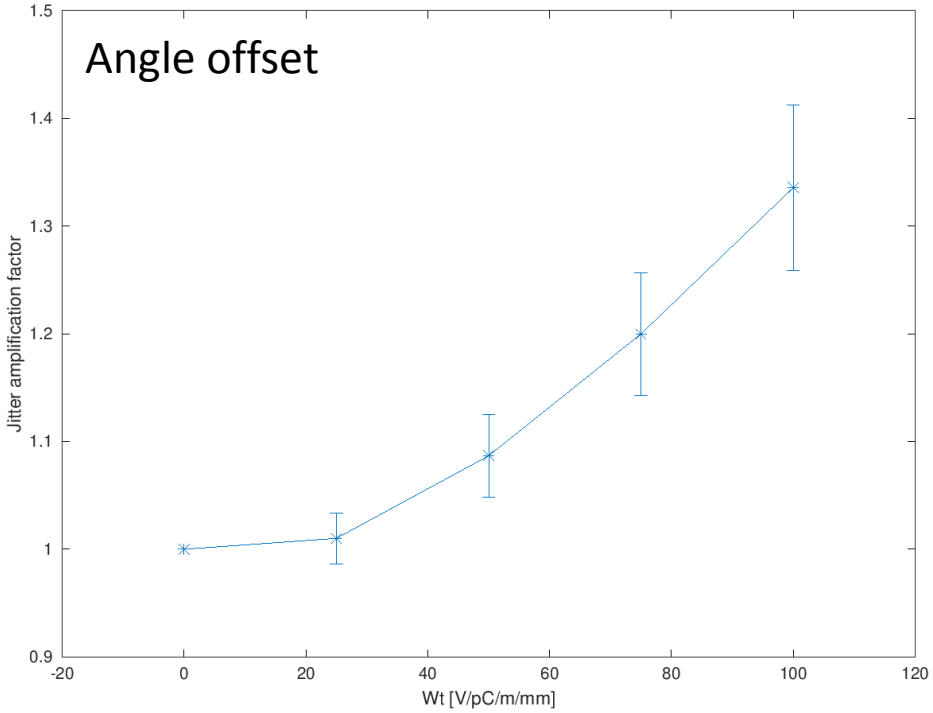




Confirms the analytical calculations

# Amplification factor at 2nd bunch

- Assume 100 um rms misalignment
- Off-axis beam injected with 10% $\sigma_{x/xp}$ offset
- 100 random misaligned machines simulated




Confirms the analytical calculations

# Conclusions

- The impact of the long-range wakefields on the emittance is negligible
- The effect of the long-range wakefields on jitter amplification seems negligible for

$$Wt < \sim 40 \text{ V/pC/mm/m}$$

($\Delta t_{2\text{-bunches}} > 350$ ps)

- **6 X-band RF cycles is OK: 0.5 ns bunch spacing.**